UNITED STATES AIR FORCE

ASSISTANT CHIEF OF STAFF,
CENTER FOR
STUDIES AND ANALYSES

METHODOLOGY FOR ASSESSING R&M IMPACTS ON FIGHTER AIRCRAFT SUSTAINABILITY

JUNE 1985

Tactical Support Division

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8501189

DEPARTMENT OF THE AIR FORCE

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WASHINGTON, D.C. 20330-5420

REPLY TO ATTN OF: SAGP

SUBJECT: Errata for AFCSA Study, Methodology for Assessing R&M Impacts on Fighter Aircraft Sustainability (June 1985)

TO:

Please exchange the attached two pages for pages i and ii of the subject study report.

JOHN P. WILHELM, Colonel, USAF
CHIEF, Tactical Support Division

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Revised Executive Summary

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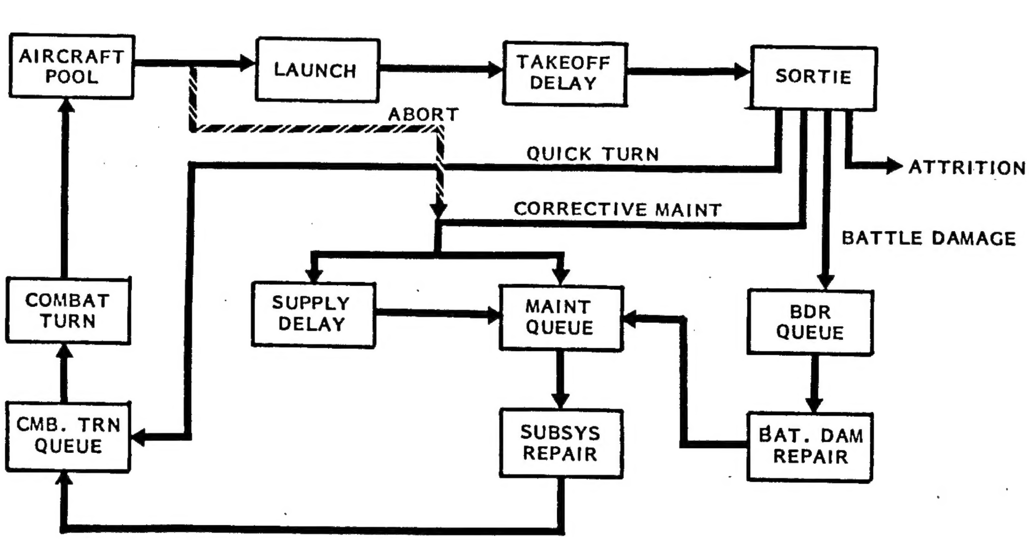
EXECUTIVE SUMMARY

The Air Force is placing increased emphasis on R&M during the early conceptual phases of new development programs. For fighter aircraft, measuring sustainability in terms of sorties generated is one way to quantify the impact of R&M. Since R&M data are very limited during these early phases, it is counterproductive to attempt the use of existing large scale simulation models; thus the Multi-Base Sortie Generation Model was developed as a simple analytical tool to study the effects of various parameters on the aircraft sortie generation process. It requires only general input data which should be available during the conceptual phases of new tactical fighter aircraft.

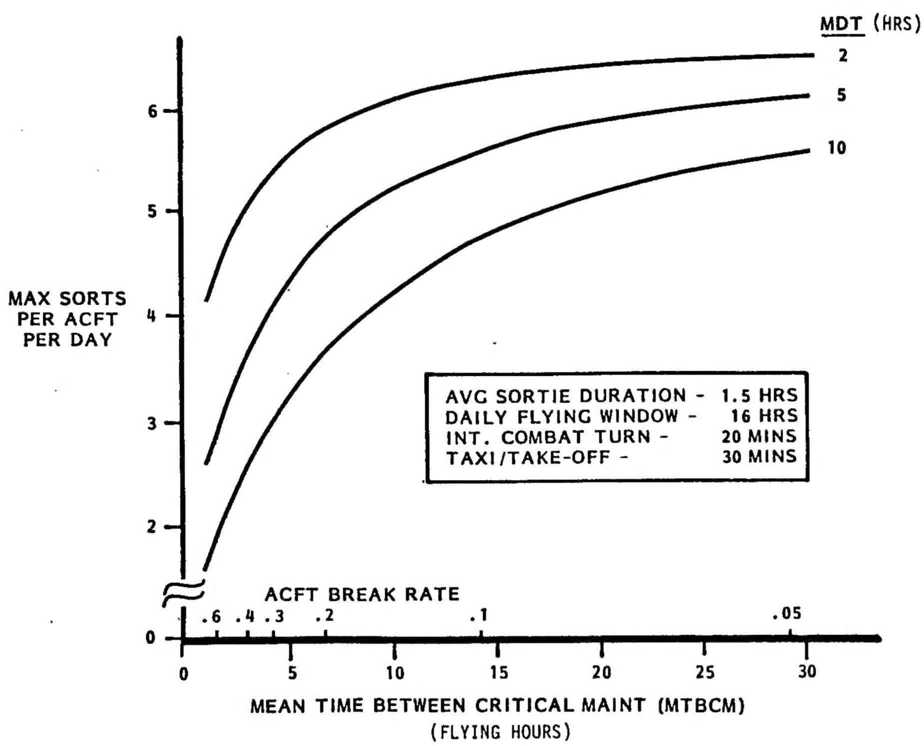
The basic flow of the Monte Carlo, discrete event simulation model is shown in the figure below.



Nonattrited aircraft are recovered and put into battle damage repair, corrective maintenance or direct combat turn around based on probabilities input by the user. In addition to the times necessary to perform these functions, the model allows for queues to form based on manpower and supply constraints.

Manpower constraints are simulated by specifying the number of teams available in each area. When sufficient teams do not exist, delays occur until a team becomes available. These teams can be reduced as a result of air base attack and increased as replacements arrive. Supply delays and their duration are also user specified.

The model provides a very useful tool for assessing the sensitivities of various R&M design parameters during the early phases of a program when data are very limited. Most of the inputs can be derived from standard R&M terms which are normally available early in the program. A parametric example which shows the relationships between mean-time-between-maintenance actions and mean down (repair) time is shown below.



This paper describes a way to obtain or estimate the input data required to use the model, and should be used in conjunction with the model's Users' Manual.

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INTRODUCTION

PREFACE

This methodology was developed as a tool for assessing the potential reliability/maintainability (R&M), supportability and survivability characteristics of the advanced tactical fighter (ATF) aircraft. This paper describes the Multi-Base Sortie Generation Model (MBSGM) and how to estimate the various data elements that are input into the model.

BACKGROUND

Reliability and maintainability (R&M) are inherent characteristics of a weapon system which have a significant impact on the system's operational capabilities and support requirements. However, the actual operational impact is not readily apparent when looking only at traditional R&M parameters. A higher level of measurement must be employed which not only considers the system's R&M characteristics, but also other areas that influence the actual performance in the field. A measure which embraces the concept of sustainability is one such measure, where sustainability is defined as the ability of a weapon system to sustain a required level of performance over a specified period of time in a specified wartime operational and support environment. The operational impact may then be reflected by R&M impact on a weapon system's sustainability.

With increased early emphasis on R&M, questions on the relationship of R&M design requirements to sustainability requirements are being asked during the early conceptual phases of new development programs. Since R&M impacts on sustainability are scenario and/or time sequence dependent, some type of simulation is normally required to quantify these relationships. Simulation models are available to conduct R&M/sustainability analyses; however, the more commonly used models are very complex and require large, detailed data bases. R&M data tend to be very limited and extremely dynamic during early program phases;

therefore, the large models are seldom useful to conduct the early R&M/sustainability analyses. As a result, there is a continuing need for simple model approaches which use the level of R&M data that is normally available during early program phases.

PURPOSE

Outline a methodology for assessing R&M impacts on fighter aircraft sustainability. The methodology uses a simple model approach, tailored for use in early program phases. Specific emphasis is on selected techniques for estimating model inputs from the level of R&M design data normally available during early program phases.

SCOPE

The methodology and techniques presented are based on concepts peculiar to tactical fighter aircraft. R&M design characteristics are addressed using the standard aircraft terminology/parameters of AFR 800-18, Air Force Reliability and Maintainability Program. Aircraft sustainability is addressed in terms of sortie generation rates in a wartime environment (i.e., sorties per aircraft per day). R&M/sustainability relationships are based on the logic of the Multi-Base Sortie Generation Model (Version 2) and the derivation of model inputs from standard R&M parameters. The structure of the model allows considerable flexibility for using different techniques to estimate model inputs. Selected R&M parameters are used to derive model inputs related to the areas of corrective maintenance, maintenance constraints, supply constraints, and combat turn around times. Although the methodology presented deals with concepts peculiar to fighter aircraft, the basic approach could be applied to other aircraft weapon systems.

SIMPLE SORTIE GENERATION MODEL

The Multi-Base Sortie Generation Model serves as the basis for this methodology. For more information see the User Manual for Multi-Base Sortie Generation Model

(Version 2), Air Force Center for Studies and Analyses.

MODEL OVERVIEW

The Multi-Base Sortie Generation Model (MBSGM) provides a simple analytic tool to study the effects of various parameters on the aircraft sortie generation process. The model addresses a single aircraft type, flying air-to-air and/or air-to-ground missions from either a single location or multiple locations (i.e., bases, dispersal locations, independent units, etc.). As presently dimensioned, the model provides the capability to simulate up to 20 locations for any specified period up to 30 days. There is no specific limit on the number of aircraft involved. The model is written to assess wartime scenarios and can partially address airbase attacks, recovery times, and ground attrition of aircraft and maintenance resources.

The technique used is Monte Carlo, discrete event simulation using a self-contained Fortran IV program. Virtually all resource, decision, and operating variables are controlled through user inputs. All user inputs can be changed at predetermined times during the simulation. Events occur at predetermined times based on input schedules or are randomly generated from input probabilities. Task times are user input and are specified using several imbedded frequency distribution options. Whereas individual task times are randomly generated from these distributions, the queuing times due to constrained resources are handled dynamically by the model. Included in the queuing logic is a triage concept where those aircraft having the shortest maintenance times are processed first. The capability exists for multiple runs, thus yielding statistical results that allow for stochastic variation. Output options include end-of-run reports, summary reports, and histograms addressing daily sortie rates, aircraft losses, abort rates, maintenance rates, and maintenance/supply downtime.

SYSTEM OVERVIEW

The system being modeled is a simplified view of units which recover returning aircraft and repair, service, rearm, and launch them according to user specified missions and sortie rates. Figure 1 illustrates the flow process for a single unit.

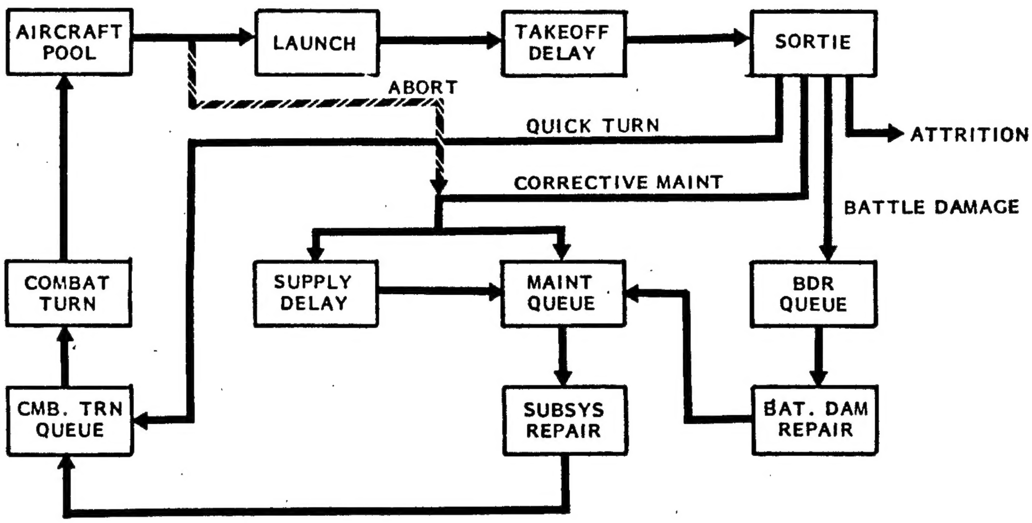


Figure 1. Simple Sortie Generation Model.

Aircraft are drawn from the available aircraft pool and, if no ground abort occurs, are launched in flights of a size specified by the user. If the specified number of aircraft are not available or if an aircraft aborts, the flight is delayed until the required number of aircraft become available. For multi-base scenarios, the user specifies the launch option as to whether all aircraft in a flight must originate from the same location or if they can originate from different bases/locations. Flights continue to launch when ready for the duration of a specified flying window (i.e., the time of day from first launch to last recovery) or until the specified sortie rate is achieved, whichever comes first. The launch times and flight times are determined by user inputs.

When the flight time has expired, aircraft are either attrited or recovered and put into battle damage repair, corrective maintenance, or a direct combat turn according to probabilities input by the user. For multi-base scenarios, the location at which an aircraft is recovered is determined by user inputs. Aircraft completing battle damage repair enter the queue for subsystem corrective maintenance; however, the user can elect to bypass this step by not inputing a requirement for post-aircraft battle damage repair (ABDR) corrective maintenance. Corrective maintenance probabilities/time distributions are input at the two-digit work unit code (WUC) level (i.e., major system/subsystem level). When more than one corrective maintenance event occurs for a given aircraft, the extent of parallel (i.e., overlapped) and sequential maintenance is based on options input by the user. Delay times (i.e., travel, tech data research, etc.) can be specified separately from the direct maintenance times. Delays due to lack of maintenance people/equipment are simulated by limiting the number of aircraft that can be in work simultaneously, thus creating waiting queues. Queuing levels result from inputs by the user, based on resource considerations external to the model. Supply delays are based on a generic spare concept with aircraft downtime determined from probabilities and time distributions input by the user. As modeled, supply downtime is accrued prior to entering the corrective maintenance queue; therefore, an aircraft cannot be in a down status for maintenance and supply at the same time. All recovered aircraft complete their maintenance cycle by undergoing an integrated combat turn and then reenter the available aircraft pool.

Although the Multi-Base Sortie Generation Model is simplistic in approach and data requirements, it has produced results consistent with other more complicated models in use throughout the Air Force. Since the model inputs are aggregated at a fairly high system level, achieving satisfactory results depends on

how the input data are derived. This is especially true when using the model to assess R&M impacts on a system's sortie generation potential.

DERIVATION OF MODEL INPUTS

The thrust of this paper is to present selected techniques for estimating inputs to the MBSGM using standard R&M parameters. The examples are based on a 24 aircraft squadron, flying air-to-air missions, with two aircraft required for each flight. The required sortie rate is set at an artificially high value and a 24 hour per day flying window is specified. This scenario provides for the maximum possible sortie generation for the defined unit and is useful to illustrate the sensitivities of sortie rates to individual R&M parameters.

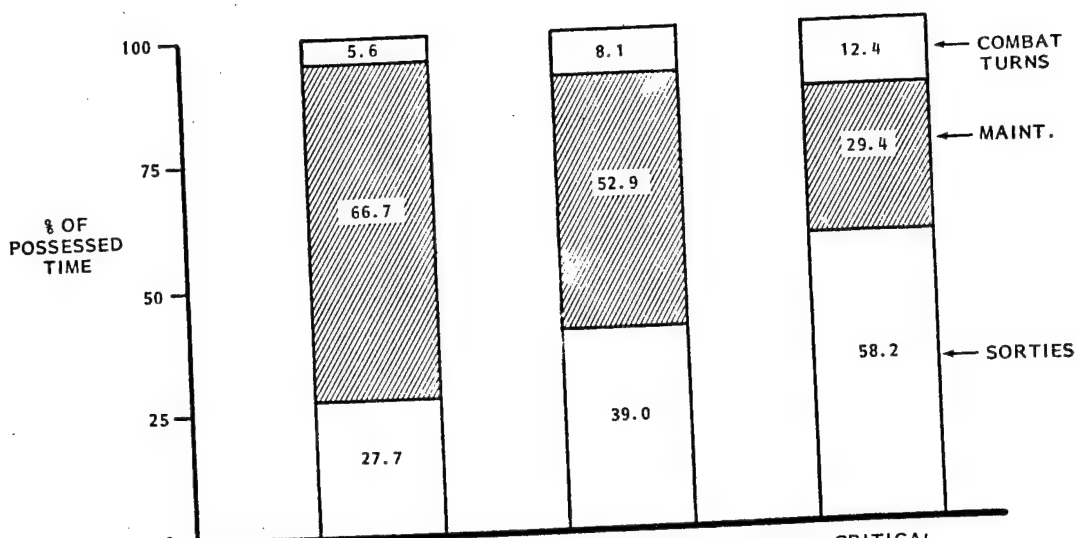
CORRECTIVE MAINTENANCE

In the MBSGM, corrective maintenance requirements are driven both by the probability of a ground abort and the probability of requiring corrective maintenance after a given sortie. The probability of a ground abort-the ground abort rate-is a direct input to the MBSGM. The probability of requiring corrective maintenance after a given sortie can be treated as a function of the average sortie duration (ASD) and the standard R&M term, Mean Time Between Maintenance (MTBM). Both the ASD and MTBM parameters are expressed in terms of flying hours. Since the MTBM parameter implies a constant event rate over time, the Poisson function can be used to determine the probability of a corrective maintenance event after a given sortie.

$$\text{PROB(MAINT, EVENT)} = 1 - \text{EXP}(-\text{ASD/MTBM})$$

In early program phases, engineering estimates of MTBM values are normally aggregated at the major subsystem level (i.e., two-digit WUC). The above equation can be used to estimate the probability of corrective maintenance for each subsystem. These individual subsystem probabilities are direct inputs to the MBSGM.

Within the USAF R&M terminology, there are many definitions of MTBM. The analyst must be aware of which MTBM definition is best suited to the analysis at hand. MTBM (Total) includes all corrective maintenance actions. MTBM (Inherent) includes only those maintenance actions due to design or manufacturing related malfunctions. MTBM (Critical) includes only those maintenance actions due to malfunctions in mission essential equipment. Therefore, the probability of an aircraft requiring corrective maintenance after a given sortie (i.e., break rate) and the resulting maintenance downtime will vary tremendously depending on which MTBM is selected. The impact of the different MTBM definitions on overall analysis results is shown by the example in Figure 2.



	TOTAL	INHERENT	CRITICAL
SYS MTBM	.57	1.68	5.67
BREAK RATE	.98	.65	.26
SORT/DAY	73.2	104.4	159.5

Figure 2. MTBM vs Maintenance Downtime.

Another consideration in using the MTBM parameter is the fact that the parameter is time based which inherently assumes that malfunctions and resulting corrective maintenance events are driven by cumulative flying hours. In reality, some subsystems/equipment may be driven by cycles of operation or number of sorties flown rather than cummulative flying hours. Landing gear is one example. If data are available, the probability of corrective maintenance for such subsystems should be based on the number of operating cycles per sortie rather than the ASD. Since the probability of corrective maintenance is an input to the MBSGM, different techniques can be used to estimate the probabilities for different subsystems.

Given the occurrence of a corrective maintenance event, the next consideration is the time required to accomplish the maintenance. This time is addressed by the standard R&M terms, Mean Repair Time (MRT) or Mean Time to Repair (MTTR). MRT is an operational term whereas MTTR is a contract term; however, both are expressed in clock hours and represent the average direct maintenance time to accomplish a maintenance event. These terms do not include administrative or maintenance/supply delay times. MRT/MTTR values for each subsystem can be directly input to the MBSGM as constants or as the means of various frequency distributions. Assumptions on the selection of a frequency distribution and the corresponding distribution parameters are left to the analyst. As an example, the Log-normal distribution is a commonly accepted assumption for maintenance times, and standard deviation to mean ratios of 0.3 to 0.6 are commonly used for maintenance analyses. There are no set rules for selecting a time distribution; therefore, the analyst is required to support any such assumptions. In any case, using the MRT/MTTR values as constants is a starting point and sensitivities can be run to assess the impacts of other assumptions.

If MRT/MTTR data are not directly available, comparable MRT values can be derived from the more commonly available R&M term, Maintenance Manhours per Flying Hour (MMH/FH). The MRT is estimated using the following relationship.

$$MRT = \frac{\text{ON-EQUIPMENT MMH/FH X MTBM}}{\text{AVERAGE MAINTENANCE CREW SIZE}}$$

The on-equipment MMH/FH represents maintenance manhours expended on flight line corrective maintenance and must directly correspond to the corrective maintenance events included in the MTBM definition being used. The average maintenance crew size for individual subsystems may be available in early planning documents. If not, estimates of crew sizes can be derived from historical data on comparable systems/subsystems. As addressed above, the resulting MRT estimates for each subsystem can be directly input to the MBSGM as constants or as the means of various frequency distributions.

In using MRT/MTTR or MMH/FH data, it should be remembered there is normally no distinction made between wartime and peacetime operations. Therefore, there is normally an underlying assumption that the average direct maintenance time for a given maintenance event is the same under all conditions. For direct maintenance times, this is not an unrealistic assumption. The greater difference is in maintenance delay time and supply delays which are addressed next.

CORRECTIVE MAINTENANCE CONSTRAINTS

In the MBSGM, corrective maintenance is constrained by limiting the number of aircraft that can undergo subsystem corrective maintenance at the same time. The limit is set using a concept of maintenance teams, where one maintenance team consists of the resources necessary to process one aircraft. The number of maintenance teams available during each maintenance shift is input to the MBSGM, thus creating the limit for the number of aircraft that can be in simultaneous work. Based on this limit, the queuing of aircraft is handled dynam-

ically within the MBSGM. The number of maintenance teams is determined externally to the model, based on consideration of key resources.

A resource that is addressed in early program phases and is sensitive to R&M design is maintenance manpower. Early estimates of manpower requirements can serve as a vehicle for estimating the number of maintenance teams to input to the MBSGM. As an example, the maintenance teams are associated with flightline corrective maintenance, therefore, the estimated number of flightline specialists can be used to estimate the number of maintenance teams. In this case, the following relationship could apply:

$$\text{MAINT TEAMS} = \frac{\text{NUMBER OF SPECIALISTS PER UNIT}}{\text{SHIFTS/DAY X CREW SIZE X MAINT EVENTS/BREAK}}$$

The number of specialists per unit is normally taken as the number assigned to the Aircraft Generation Squadron (AGS). In wartime, the number of shifts per day is normally assumed as two (12 hour shifts). The crew size is the average number of specialists required to accomplish a maintenance event. The crew size can be determined from historical data on a comparable system or can be estimated using the standard R&M parameters MTBM, MMH/FH, and MRT discussed in the previous section. In the latter case, the following relationship could apply:

$$\text{CREW SIZE} = \frac{\text{ON-EQUIPMENT MMH/FH X MTBM}}{\text{MRT}}$$

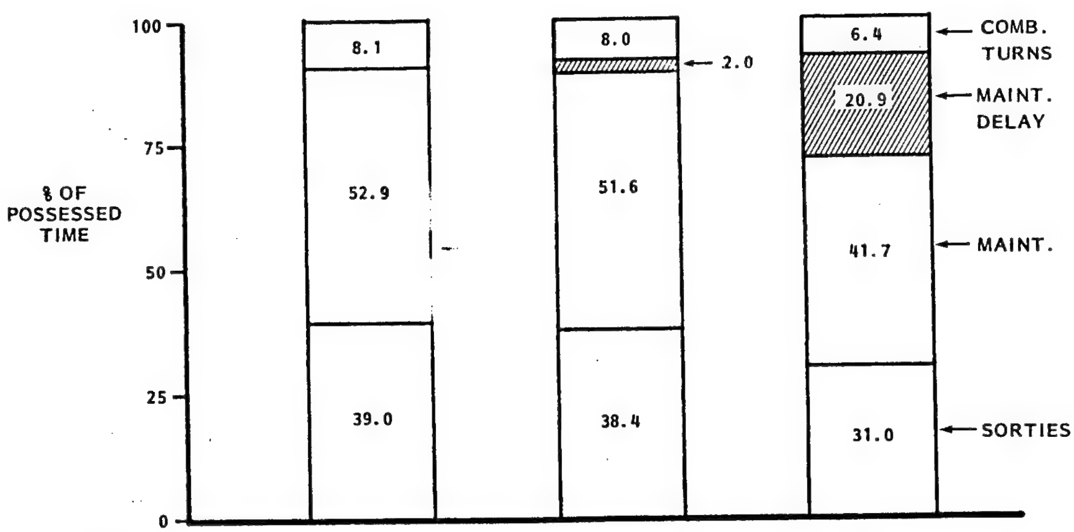
Since maintenance teams are applied to the whole aircraft, the R&M parameters used here are aggregated to the total system level. This creates an inherent assumption of generic specialists; however, such an assumption is normally necessary in early program phases when data on specific maintenance specialities are not available. The last parameter in the maintenance team equation, that is events per break, is the average number of maintenance events required

to be accomplished when an aircraft is down for corrective maintenance (i.e., aircraft break). The events per break are normally determined from unconstrained runs of the MBSGM; however, an estimate can be made using the average sortie duration (ASD) and MTBM parameters. In the latter case, the following relationship could apply:

$$\text{EVENTS/BREAK} = \frac{\text{ASD}}{\text{MTBM X }[1 - \text{EXP}(-\text{ASD/MTBM})]}$$

Using the above relationships, the number of corrective maintenance teams can be estimated with the resulting number being a direct input to the MBSGM.

Since the number of corrective maintenance teams is determined externally to the MBSGM, other considerations (i.e., available support equipment) can be used to adjust the model input. Sensitivities to different numbers of maintenance teams can be quickly assessed. Using the inherent MTBM example from Figure 2 as a baseline, the sensitivity of simulation results to different numbers of maintenance teams is shown in Figure 3.



MAINT TEAMS	24	14	10
DELAYS/DAY	0	21.0	53.4
AVG DELAY (HRS)	0	.56	2.2
SORT/DAY	104.4	103.0	82.7

Figure 3. Maintenance Teams vs Maintenance Downtime.

SUPPLY CONSTRAINTS

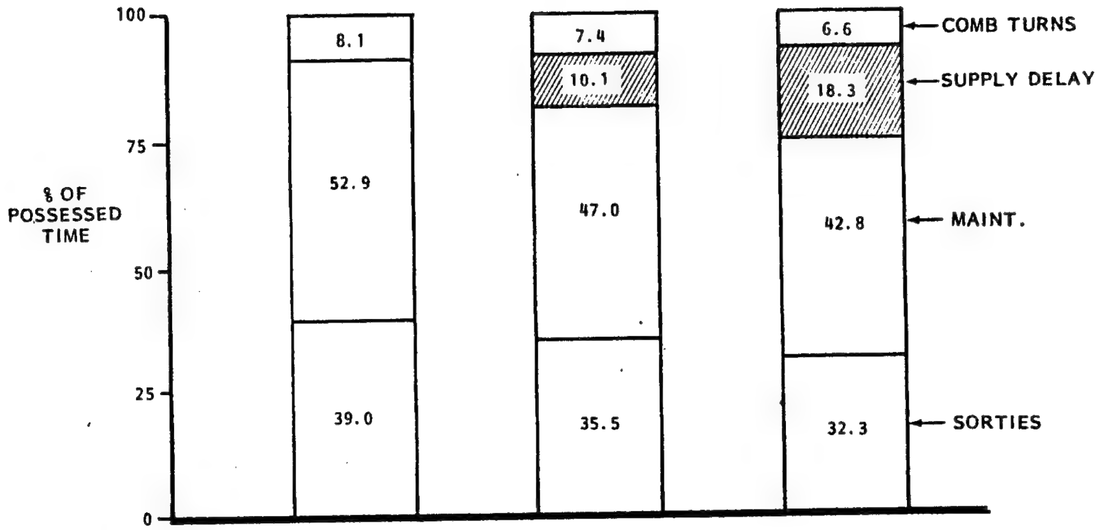
In the MBSGM, an aircraft is put in a down for supply status based on the probability of such an occurence, given that an aircraft has a requirement for corrective maintenance (i.e., aircraft is broken). The probability of a broken aircraft experiencing a supply delay can be estimated using the standard R&M terms MTBM and Mean Time Between Demand (MTBD). The following relationship would apply

$$\text{PROB(SUPPLY DELAY)} = \text{EVENTS/BREAK} \times \frac{\text{MTBM}}{\text{MTBD}} \times \text{(1-SPARE OBJ)}$$

The maintenance events per break are the same as discussed in the previous section. The ratio of MTBM to MTBD represents the percent of corrective maintenance events which cause a demand for spares. This ratio may be adjusted to account for cannibalization actions when such a policy will apply. The sparing objective is the probability of having the spare being demanded and equates to a stocking level goal. It is assumed that future funding will support the stated sparing objective. The probability of a supply delay addresses the aircraft as a whole; therefore, there is an inherent assumption of generic spares. In early program phases, individual spares are not normally identified; therefore, the generic spare assumption is a matter of necessity. The probability of a supply delay is a direct input to the MBSGM.

Given that a supply delay occurs, the length of the delay is input to the MBSGM either as a constant or as a time distribution. The length of the supply delay is based on assumptions of supply system responsiveness. As an example, wartime planning frequently calls for no resupply in the first 30 days. In this case, once an aircraft is down for supply, it will stay down for the duration of the 30 day war. In the MBSGM, this case is handled by entering a supply delay time in excess of 720 hours (i.e., 30 days). Assumptions on delay time distributions are left to the discretion of the analyst.

Using the inherent MTBM example from Figure 2 as a baseline, Figure 4 shows the sensitivity of different MTBM/MTBD ratios and sparing objectives on overall simulation results. In these examples, a constant delay time of 24 hours is assumed.



MTBM/MTBD	.45	.45	1.0
SPARE OBJ.	1.0	.95	.95
DELAY TIME (HRS)	0	24	24
DELAYS/DAY	0	2.4	4.5
SORT/DAY	104.4	95.3	85.4

Figure 4. MTBM/MTBD vs Supply Downtime.

SCHEDULED MAINTENANCE

The MBSGM does not include a separate maintenance flow for scheduled maintenance. Normally, it is assumed that scheduled maintenance will be deferred during the first days of a wartime scenario. However, scheduled maintenance may be included in the MBSGM in either of two ways. One way is to assume that scheduled maintenance requirements, such as phased inspections, will cause a certain percentage of the possessed aircraft to be down at any given time. In this case, that number of aircraft are deleted from the simulation. As an example, if it is assumed two of a 24 aircraft squadron are in scheduled mainte-

nance at any given time, the simulation is run with 22 aircraft rather than the original 24. The other technique is to assume that scheduled maintenance will only be accomplished when an aircraft is down for corrective maintenance. In this case, a dummy subsystem is created to represent the scheduled maintenance or a prorated maintenance time is entered in the model as a maintenance delay when corrective maintenance occurs. If scheduled maintenance times are available, the latter technique is preferred in that it includes the consideration of scheduled maintenance into the maintenance flow. In addition, the assumption that scheduled maintenance, if required, will be accomplished in conjunction with corrective maintenance is considered to be more realistic for a wartime environment.

INTEGRATED COMBAT TURN AROUND TIME

In the MBSGM, each recovered aircraft completes its maintenance cycle with an integrated combat turn around time. If no other maintenance is required, the aircraft goes directly to the combat turn around upon landing. As with other maintenance times, the combat turn around time is input to the MBSGM as a constant or as a frequency distribution. Assumptions as to a frequency distribution are left to the analyst. One method is to use a step distribution derived from a timeline of the key tasks required during a combat turn. Figure 5 shows two examples of such an analysis.

The timeline shows the key tasks accomplished by both the munitions loading crew and by the aircraft maintenance crew. The probability of the task being required is based on such considerations as the probability of engagement and the probability of expending munitions or other expendables during a given sortie. Of course, basic servicing tasks are always required. The sequencing of the tasks and the time to accomplish each task is dependent on the crew size. In

the examples of Figure 5, the solid lines represent a 4-person load crew while the dotted lines represent a 3-person load crew. A 3-person maintenance crew

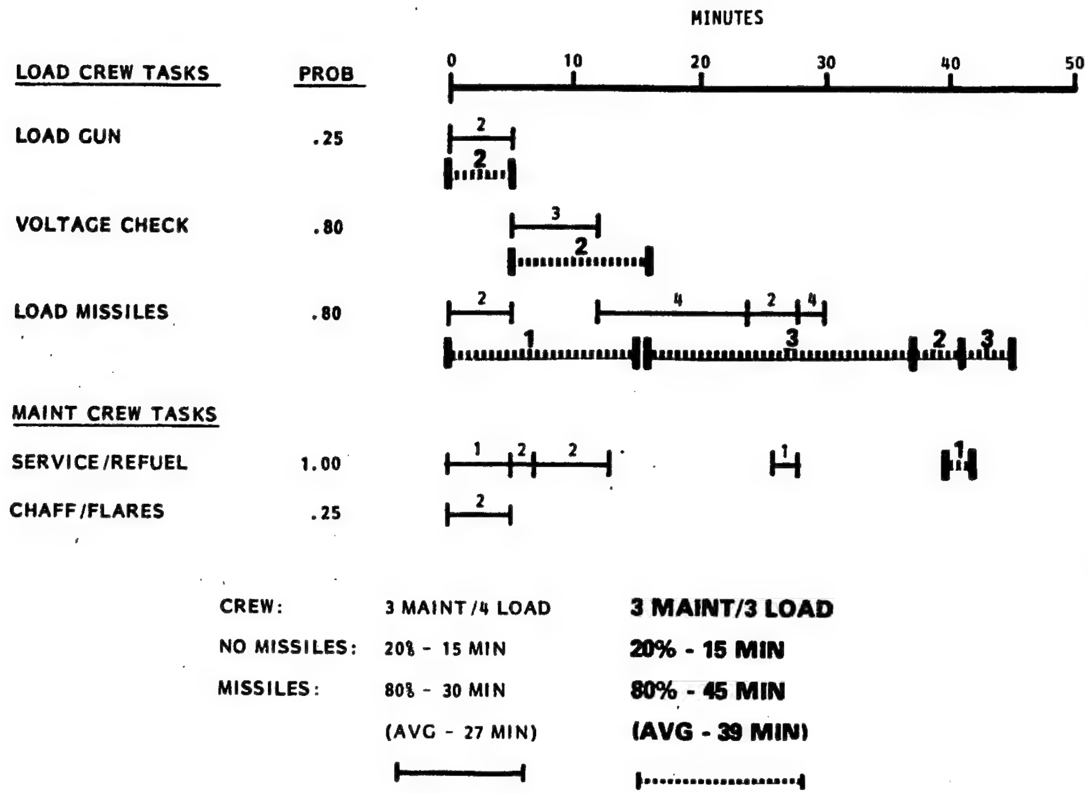


Figure 5. Combat Turn Around Tasks/Timeline.

is used in both examples. The resulting step distributions for the complete combat turn around are 20% in 15 minutes and 80% in 30 minutes for the 4-person load crew; whereas the 3-person load crew has a distribution of 20% in 15 minutes and 80% in 45 minutes. These type of step distributions can be directly input to the MBSGM.

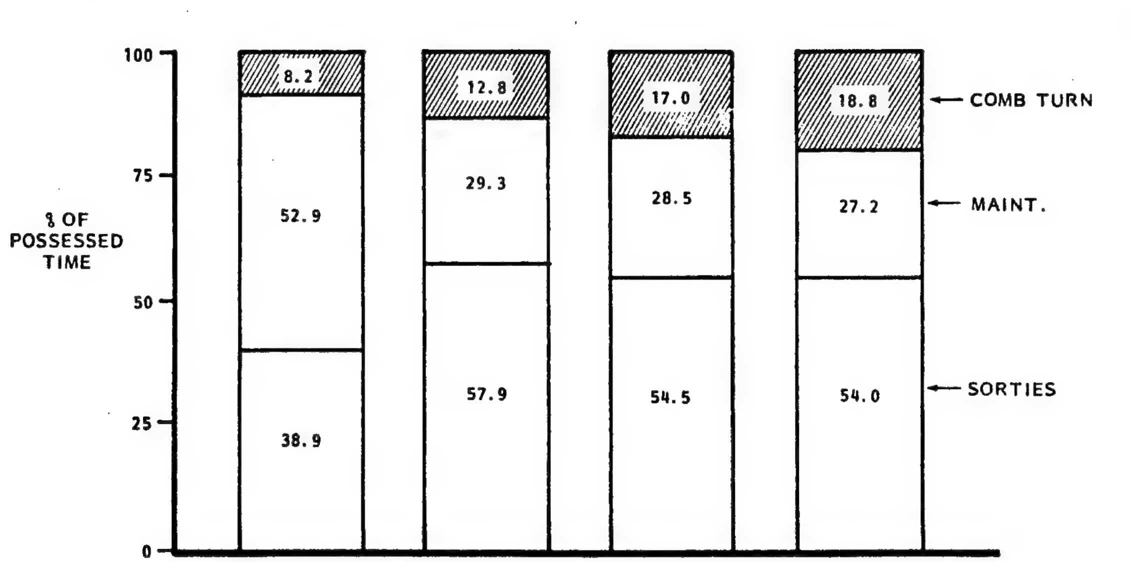
As with the corrective maintenance, the combat turn around maintenance is constrained in the MBSGM by limiting the number of aircraft that can undergo combat turn arounds at the same time. Again, the limit is set using a team concept. Normally, combat turn arounds are most sensitive to the munitions loading

tasks; therefore, using munitions loaders as a key resource is a good vehicle for estimating the number of combat turn around teams. In this case, the following relationship could apply.

$$\text{COMBAT TURN AROUND TEAMS} = \frac{\text{NUMBER OF LOADERS PER UNIT}}{\text{SHIFTS/DAY} \times \text{CREW SIZE}}$$

The number of loaders per unit is normally taken as the number assigned to an Aircraft Generation Squadron (AGS). The number of shifts per day in a wartime environment is normally set at two. The crew size is the desired load crew size. The resulting number of combat turn around teams is a direct input to the MBSGM.

Using the time distributions from the examples in Figure 5, the sensitivity of simulation results to combat turn around times and the number of combat turn around teams is shown in Figure 6. It is noted that the impact of combat turn around times varies depending on which corrective maintenance rates are used in the simulation.



CORR MAINT	INHERENT	CRITICAL	CRITICAL	CRITICAL
LD CREW/TEAMS	4/5	4/5	3/7	3/5
TURN TIME (MIN)	27	27	39	39
% C-T DELAY	.00	1.5	0.3	2.3
SORT/DAY	104.0	158.4	149.0	147.2

Figure 6. Combat Turn Around Time vs Downtime.

BATTLE DAMAGE REPAIR

In the MBSGM, battle damage repair requirements are driven by the probability of incurring aircraft battle damage on any given sortie. The probability of battle damage is normally determined as a ratio to the probability of attrition on a given sortie. This ratio is input to the MBSGM to specify the probability of battle damage. Attrition and battle damage probabilities are very dependent on threat/scenario definitions which are beyond the scope of this paper.

Given that battle damage repair is required, the repair time is input to the MBSGM either as a constant or as a frequency distribution. Battle damage repair times are frequently expressed in terms of the percentage of repairs to be accomplished within 24 hours. Given these data, a common assumption is to use an exponential distribution which provides the stated percentage in 24 hours. However, as before, assumptions on battle damage repair times are left to the analyst.

In the MBSGM, battle damage repair is constrained using the same team concept as is used to constrain corrective maintenance and combat turn around. A common assumption is that a typical 24 aircraft squadron has an inherent capability equal to one battle damage repair team. Additional teams must be based on those resources which are deployed in wartime to supplement the aircraft squadron, such as a Combat Logistics Support Squadron (CLSS). From a manpower standpoint, a common assumption is that one battle damage repair team consists of approximately six people. Therefore, a CLSS which includes 30 people for battle damage repair would provide the equivalent of five battle damage repair teams. The number of battle damage repair teams is a direct input to the MBSGM and it can be time-phased over the period of the simulation.

CORRECTIVE MAINTENANCE IMPACTS

The main concern of most R&M analyses is the impact of corrective maintenance on system operations. The impact of corrective maintenance on sortie generation capabilities is driven both by the frequency of maintenance and the time required to restore the aircraft to an operational condition. Figure 7 shows the relationship between sortie rate, maintenance frequency (i.e., MTBM), and mean downtime (MDT).

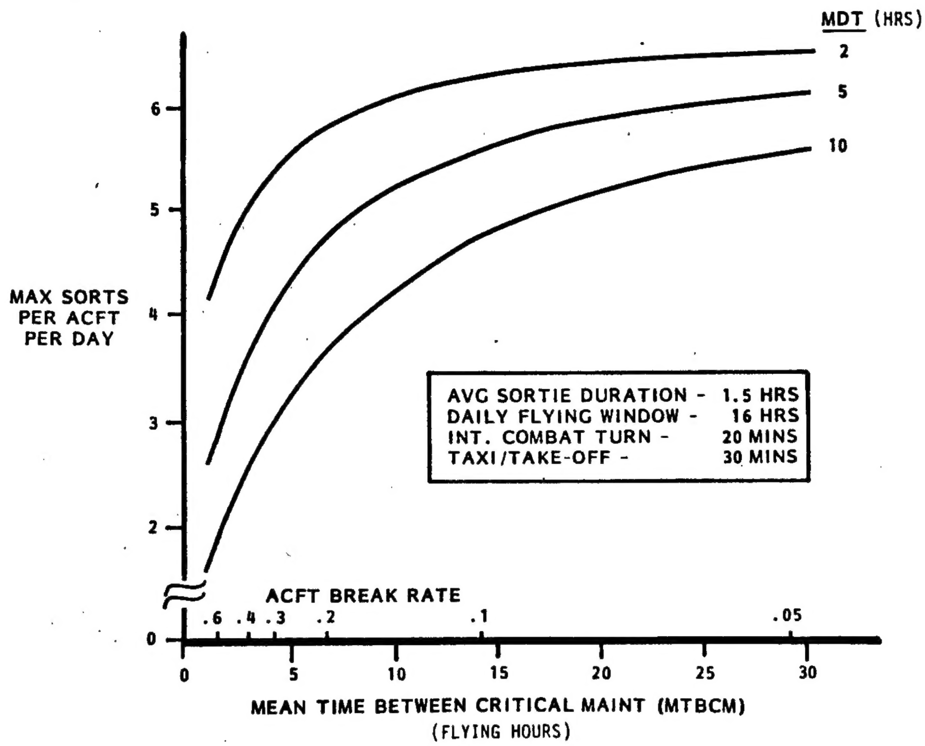


Figure 7. Sortie Rate vs Aircraft Reliability and Maintainability.

Here, the MDT includes the direct maintenance time (i.e., MRT) plus maintenance delay and supply delay times. The correlation of overall aircraft break rate to MTBM is also shown.

COMPOSITE ANALYSIS

In earlier sections of this paper, sensitivities were shown for individual parameters or factors while holding all other inputs at their unconstrained values. Such sensitivity analyses do not show the complete picture in that the interplay of all the factors is necessary for a complete analysis. An example of this interplay is depicted by the composite analysis shown in Figure 8.

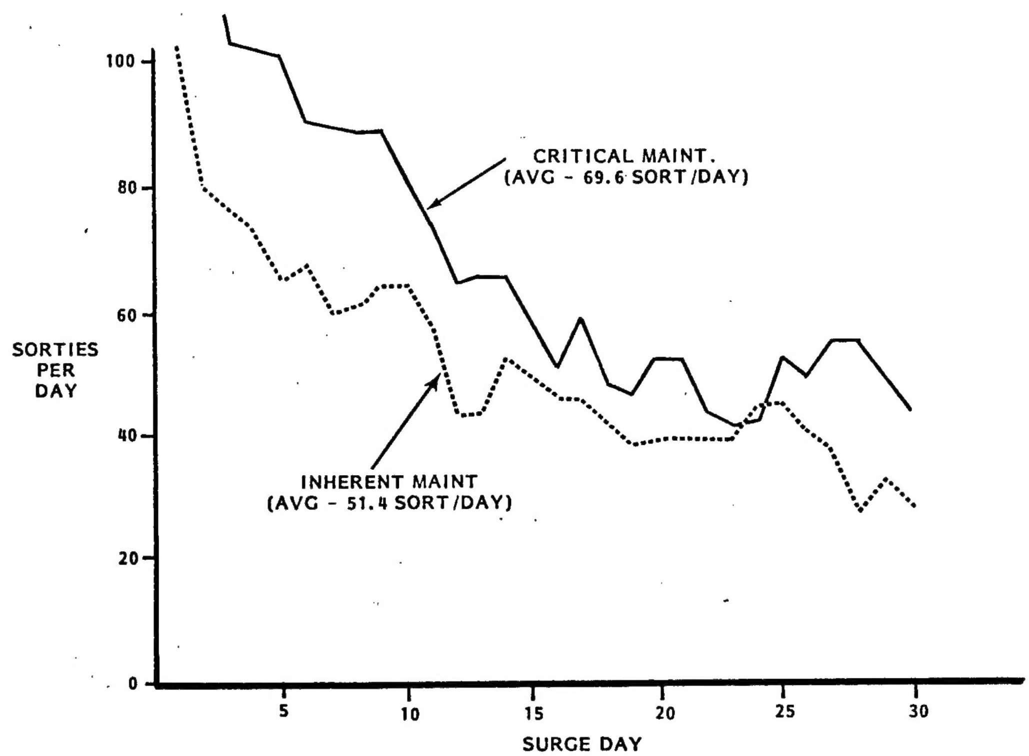


Figure 8. Composite Analysis Results.

This example depicts the drawdown in sortie generation capability over a 30-day war for both the inherent and critical maintenance rates used in earlier sections. This example uses a 1% attrition rate (100% fillers), a 2:1 ratio of battle damage to attrition, and a 1% ground abort rate. Maintenance constraints are based on 14 corrective maintenance teams, five combat turn teams, and one battle damage repair team. This type of composite analysis addresses the real

measure of sustainability in that it shows the sortie generation capability which can be sustained over a period of time. The impacts of various R&M parameters, or combinations of R&M parameters, then become readily apparent.

SUMMARY

Simple sortie generation models provide a tool to look at the sensitivity of sustainability to R&M design parameters. This is especially true in early program phases when there is a limited amount of data, thus making the use of larger complex models infeasible or too time consuming. This paper presented some techniques to derive the inputs to one such simple model, the Multi-Base Sortie Generation Model (MBSGM). The inputs were derived using the standard R&M terms which are normally used to evaluate design characteristics in early program phases. The basic techniques presented here are not necessarily peculiar to the MBSGM and should provide insight for estimating R&M inputs to other models using similar inputs.